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The Effect of Carbon Sink Plantation Projects on Local Economic Growth: An Empirical Analysis of County-Level Panel Data from Guangdong Province

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Abstract: In recent years, there has been an increased focus on carbon sink plantation projects. Carbon sink plantations can slow global climate change and promote sustainable economic development, which is well suited to the needs of both ecological protection and economic growth. This article aims to accurately assess the causal effect of carbon sink plantation projects on economic development at the county level and explore its effect mechanisms. In this study, 56 counties in Guangdong Province were selected as the research areas, providing balanced panel data from 2006 to 2018. Then the propensity score matching and difference-in-differences (PSM-DID) model was used to estimate both the average and dynamic effects of carbon sink plantation projects on county-level economic development. The ordinary least squares (OLS) multiple regression results of the single-difference method and difference-in-differences (DID) model show that carbon sink plantation projects have a significant role in promoting county-level economic development. In addition, our findings suggest that the economic benefits of carbon sink plantation projects began to gradually appear from the sixth year after the projects were implemented.

Keywords: carbon sink plantation project; forestry carbon sink; PSM-DID model; county-level economy

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1. Introduction

Forests are an essential component of the Earth's ecosystem and have economic and ecological functions [1]. As the effects of global climate on modern society become increasingly severe, the international community has begun to pay greater attention to the ecological function of forests [2], especially their function of absorbing carbon dioxide and directly or indirectly improving the climate and environment [3]. After the Kyoto Protocol came into effect, forestry carbon sinks were officially added to the transaction types of clean development mechanism projects, which have since been widely regarded as an important way to deal with climate warming [4,5]. The term "forestry carbon sink" refers to activities and mechanisms that absorb carbon dioxide in the atmosphere to offset carbon emissions through afforestation, reforestation, forest management, and other activities. After reaching the carbon dioxide emission standards allocated to China by the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, the remaining forestry carbon sinks can also be available for carbon trading in the international market. Forestry carbon sinks not only play an important role in dealing with global climate change but also benefit the construction of China's 'ecological civilization'. China's economy is currently undergoing a green, low-carbon transition period, and forestry carbon sinks are in line with the transformation requirements of carbon emission reduction and the establishment of an environmentally friendly society [6,7]. The Carbon Sink Plantation Project, as the main body of forestry carbon sinks, refers to the project activities that rely on market carbon sink circulation to achieve ecological compensation and measure the value of carbon sinks during the growth period of forest trees. Its comprehensive effectiveness is well-aligned with a win-win model of economic growth and ecological protection in China [8].

However, the current forestry carbon sink project implementation system in China, as well as globally, is not yet mature. From an economic perspective, while having positive effects on economic development, it will also inevitably have some negative effects: it may deprive forest farmers of opportunities to increase family income through other non-forest activities [9,10], and the development of forestry may also hinder the development of the agricultural industry. At the same time, the carbon sink plantation project is an economic project with high initial investment and a long return period. The short-term economic benefits may be hard to establish because of multiple difficulties such as potential forest farmers' conflicts, opportunity cost issues, low willingness of farmers to participate, and fiscal budget issues during the implementation of the project.

There are still some deficiencies in existing studies. First, most studies discuss the relationship between carbon sink plantation projects and the economy in just the theoretical framework [11,12] and rarely conduct empirical studies to analyze its economic effects at the regional level. Secondly, most of the empirical studies on project effects use the single difference method, which only compares the changes in the regional economy before and after the implementation of the project, which cannot eliminate other influencing factors and determine the net effect of carbon sink plantation projects implementation on local economic development. Finally, although most of the literature has indicated that carbon sink plantation projects have a positive effect on economic development [13], the mechanism and sustainability of this effect have not been studied in depth. So, what is the economic effect of the implementation of carbon sink plantation projects at the county level? What is its effect mechanism? Accurately estimating the causal effect of carbon sink plantation projects on county level economic development has important practical significance.

Therefore, in response to the abovementioned problems, this article has tried to adopt the following improvements. This article includes Guangdong Province, one of the first pilot provinces for carbon sink plantation projects in China, as the research area, taking full discussion of the economic value of carbon sink plantation projects as the research objective. On the basis of theoretical analysis, it is planned to eliminate the endogenous problems caused by other variables on the research results through the empirical analysis of the propensity score matching and difference-in-differences (PSM-DID) model, so as to accurately estimate the causal effect of the implementation of carbon sink plantation on county-level economic development in China and finally analyze the mechanism of this effect.

The structure of this paper is as follows. The second section includes a related literature review and motivation. The third section provides a qualitative analysis of how carbon sink plantation projects affect economic development in different aspects and provides a theoretical basis for the empirical part. The fourth section reviews our data sources and variable settings. The fifth section displays and describes the empirical results. The final section summarizes the implications of these results and comments on their potentially broader insight for future carbon sink projects.

2. Literature Review

The main focus of both the Kyoto Protocol and the European Union (EU) climate policy is to reduce the carbon content in the atmosphere, which can be achieved not only by reducing carbon dioxide emissions but also by increasing carbon sinks [14]. The literature on calculating the cost of carbon emissions shows that the marginal cost of carbon sinks enhancement is lower than that of carbon emissions [15,16]. According to available statistics, carbon sink plantation projects can obtain investors' funds more readily than other simple reforestation projects [17,18]. Innovative forms of carbon financing, such as financing for the development of Clean Development Mechanism (CDM) projects, low-carbon transformation financing for enterprises, and financing for emission trading projects, can significantly increase local fiscal revenue and promote regional economic development [19]. Hu Yuan et al. [20] found that the implementation of carbon sink plantation projects has

significantly promoted the growth of real gross domestic product (GDP) per capita in Sichuan province through empirical research and analysis of econometric models.

The implementation of carbon sink plantation projects is an important way to reduce poverty and prevent economically underdeveloped areas from returning to poverty [21–24]. Carbon sink plantation projects can improve the ecological environment, thereby directly reducing the risk of poverty to farmers caused by natural disasters and improving the local ability to resist harsh natural environments or natural disasters [25]. Carbon sink plantation projects play an important role in the development of biomass energy and the optimization of the industrial structure in rural areas and provide continuous impetus for economic growth [26]. Wim Carton et al. [27] pointed out that in a community in Mozambique, a carbon sink project promoted agroforestry and reforestation activities, as well as other derivative economic activities, to maximize the participation of the poor and the effect of poverty reduction. By participating in carbon sink plantation projects, farmers can obtain employment opportunities, increase income levels, and improve their quality of life [28–31].

However, carbon sink plantation projects also have many risks that endanger economic benefits, such as capital restrictions that take the unequal investment return brought about by the high investment and low income at the initial stage of project operation as the main problem, complex governance system planning and legal formulation issues, as well as a certain degree of natural and political risk caused by the long-term nature of afforestation projects [32,33].

3. Effect Mechanism

On the basis of the studies discussed above, this section includes a qualitative analysis of how carbon sink plantation projects affect economic development on several different levels, and it provides a theoretical basis for the empirical part of the study of its effect mechanisms.

3.1. Carbon Sink Plantation and Industrial Structure

In terms of industrial structure, a carbon sink plantation can promote the professionalization of forestry as a primary industry by improving the level of forest resource management, and it can reduce the deforestation or destruction of forests by converting ecological value into economic value, thereby promoting the internal structural adjustment of the primary industry. For example, in the process of forest management, to maintain the sustainable development of a project, more attention will be paid to the quality of forest management, so as to improve the monitoring level of local forest resources and rationally organize management and reforestation.

At the same time, each carbon trading market sets emission control standards on the basis of emission control targets and requires specific key emission units or enterprises to control their emissions. Generally, the more developed the carbon market, the greater the number of emission control companies in the region [34]. To avoid administrative penalties or more serious consequences for excessive carbon emissions, industrial enterprises with high energy consumption and high pollution will spontaneously purchase carbon allowances or participate in carbon sink plantation projects to offset industrial pollution in the form of carbon trading [35]. In the long run, it can also promote the spontaneous transformation of such enterprises to low-carbon ones, by accelerating the development of new technologies, using clean energy and other means to reduce emissions, thereby improving the status quo of the development of the secondary industry in Guangdong Province.

With the continuous development of carbon sink plantations, tertiary industries such as forest healthcare-based tourism, which have had rapidly increased demand in recent years, can also rely on it to continue to grow. Therefore, a carbon sink plantation can optimize the internal structure of the primary and secondary industries and promote the development of the tertiary industries.

3.2. Carbon Sink Plantation and Capital Accumulation

At present, China's main carbon sink plantation finance method is realized through the establishment of a special carbon sink fund by the China Green Carbon Foundation, and all sectors of society can invest in projects through this platform. Therefore, carbon sink plantation projects can broaden regional financing channels, various innovative ways of carbon finance will attract diversified social capital investment from companies or individuals other than the government.

In addition, the carbon sinks in the project have the attributes of market transactions. Carbon trading can convert the ecological value of forestry into tangible economic value. Therefore, carbon sinks can not only be used as collateral for loans to financial institutions, but they can also reduce the difficulty of applying for long-term forestry loans in the region, thereby reducing the financing difficulties faced by development. For example, in 2016, Daxing'anling Tuqiang Forest Farm used carbon sink income rights as a pledge to loan 10 million yuan to Daxing'anling Rural Commercial Bank. In recent years, successful cases of carbon sink plantation pledge loans have also appeared in Fujian, Jiangsu, and other provinces. However, the development of the current carbon market needs to be improved. Compared with other products, the willingness of financial institutions to invest in carbon sink plantations is not strong. The individual practice of this form of pledged loans cannot represent the general acceptance in the financial market.

In short, carbon sink plantations can contribute to regional economic development by stimulating the vitality of carbon finance.

3.3. Carbon Sink Plantation and Fiscal Revenue and Expenditure

At present, the main body of investment in domestic carbon sink plantations is still the government, and the development of carbon sink plantations is closely related to the government's fiscal revenue and expenditure. In terms of fiscal revenue, carbon sink plantations have enabled local forestry resources to generate diversified economic benefits and increased government revenue. After a carbon sink plantation is added to the carbon trading market, the local forestry resources and other related biological resources can generate economic benefits through market entry mechanisms and deepen carbon finance in rural areas at the same time.

Furthermore, in terms of expenditures, although the limited budgetary expenditures of local governments after investing in carbon sink projects may have a crowding-out effect on other aspects of capital investment due to the large investment in the preliminary project, these financial problems will be solved by waiting for the long-term carbon sink project profits to increase, and the financial income generated by the project's profits can be returned to other parties, thereby promoting the sustainable development of the local economy.

3.4. Carbon Sink Plantation and Household Savings

The direct beneficiaries of the carbon sink plantation projects are local farmers. Production activities such as forest planting, management and protection, fertilization, and fire prevention during the annual operation of the project require labor, can bring long-term stable jobs to local residents. Local residents can also diversify their sources of income through other economic activities such as forest land investment, property rights transfer, participation in reforestation, development of forest health and forest tourism, and other related service industries. In joint-stock cooperative carbon sink plantation projects, farmers can also receive dividends from carbon sink sales. For example, the carbon sink plantation project in Shawo, Xin County, Henan Province adopts the model of "company + cooperative + farmer", giving priority to employment of local poor households in terms of labor demand, and 60% of the project income is used for villagers' dividends. Carbon sink plantation projects enhance the viability of remote farmers by providing them with job opportunities, thereby achieving sustainable savings growth.

In general, carbon sink plantations can increase the per capita and regional GDP levels by promoting the optimization of the industrial structure, stimulating the vitality of carbon finance, improving fiscal revenue and expenditure, and increasing the savings of local residents. However, a carbon sink plantation project is an economic project with high initial investment and a long return period. The short-term economic benefits may be hard to establish because of multiple difficulties such as potential forest farmers' conflicts, opportunity cost issues, low willingness of farmers to participate, and fiscal budget issues during the implementation of the project. Based on this, this paper uses the PSM-DID model to study the average effect and dynamic effect of carbon sink plantation projects, further analyzes its effect mechanism, and proposes the following research hypotheses:

Hypothesis 1. *The implementation of carbon sink plantation projects can promote the development of the county-level economy in Guangdong Province.*

Hypothesis 2. *The economic benefits of carbon sink plantation projects have a significant lag; that is, the economic benefits are not obvious in the early stage of project implementation, but as time goes by, their role in promoting county-level economic development will gradually increase.*

Hypothesis 3. *The effect mechanisms of carbon sink plantation projects in promoting local economic development include: promoting the development of primary and secondary industries, increasing local fiscal revenue and expenditure, increasing household savings, and enhancing the vitality of financial loans.*

4. Model Construction, Data, and Description of Variables

4.1. Samples and Data

Guangdong Province is a major forestry province in China, with a forest area of 1.106 million hectares and a forest coverage rate of 56%. According to the available statistics, Guangdong's annual carbon emissions exceed 300 million tons, accounting for more than one-tenth of the country's total. It is also one of the first pilot provinces for forest carbon sink projects in the country. To achieve emission reduction targets, Guangdong Province has been committed to improving the quantity and quality of forestry resources for several consecutive years, and the degree of development of carbon sink plantations is now at the forefront of all provinces in China. In 2011, the Changlong Carbon Sink Plantation Project was implemented in the relatively underdeveloped barren hills of Guangdong Province, where the carbon sink plantation areas of Wuhua County, Xingning City, Zijin County, and Dongyuan County were 266.7 ha, 266.7 ha, 200.0 ha, and 133.3 ha, respectively. In May 2015, the first phase of the project's emission reductions was issued, making it the first Chinese Certified Emission Reduction (CCER) Project to receive emission reductions issued by the National Development and Reform Commission. The Changlong Carbon Sink Plantation Project in Guangdong Province is the most representative because of its long implementation time and established project operation [36]. Therefore, this study includes four counties that are implementing the Changlong Carbon Sink Plantation project as the treatment group and other counties that have not implemented the project as the control group. In view of the fact that there are individual counties (districts) in Guangdong Province that have undergone changes at the administrative level, we exclude these counties from the empirical study. At the same time, we take 2011 as the starting point for the effects of carbon sink plantation policy, and select 6 years before the policy time point, that is, 2006–2011, and 7 years after the policy time point, that is, 2012–2018, as the sample period for policy evaluation. Finally, panel data of 56 county samples from 2006 to 2018 were collected.

The data selected in this study are mainly sourced from the China County Statistical Yearbook, the Guangdong Rural Statistical Yearbook, and the Guangdong Statistical Yearbook for the years of interest.

4.2. Model Construction

The site selection of carbon sink afforestation projects has strict requirements on objective factors such as land type, property rights, and area. However, there is a positive relationship between natural conditions and economic levels, which will affect the research results of this study via factors arising from differences in the natural environment that are omitted or difficult to include in the model, resulting in inevitable endogeneity. Therefore, we tried to use the DID method to account for the presence of endogenous problems, test the net effect of the carbon sink afforestation project on the county economy, and accurately evaluate the policy effect of the project implementation. Because of the different economic development speeds and levels of the counties in Guangdong Province, the treatment group and the control group, which were obtained by matching only the implementation of the project in the total sample, may have significant differences in originality, which in turn makes the research results appear to have some degree of deviation. Therefore, before running the DID model, we used the propensity score matching (PSM) method to match the treatment group and the control group. When performing PSM, we first divided each sample county into two categories: counties where carbon sink afforestation began in 2011 are treated as the treatment group, and counties that have never participated in the carbon sink afforestation project as of the time of the study are the control group. This study used the kernel matching method to match each treatment group and the control group that is not affected by the policy (before 2011). For example, the goal is to find county A in the control group and make it as similar as possible to the observable variables of county B in the treatment group that implements carbon sink afforestation. If a county's participation in the project and the probability of participating in the project completely depends on the abovementioned observable control variables, the two counties have a similar probability of implementing the policy. The PSM method calculates the propensity score according to the matching index, and then matches the sample of individuals included in the treatment and control groups based on the similarity of the propensity score between them, which can reduce the estimation error caused by sample selection bias and, thus, improve the credibility of the empirical study results. Then, in the new matched samples, the policy effects of carbon sink afforestation on regional economic development were examined according to the DID method.

The DID model is commonly used in policy analysis and project evaluation, and is usually used to estimate the net effect of a policy or project. It can be used to solve the aforementioned endogenous problems that cannot be quantified, and then evaluate the net effect of carbon sequestration afforestation projects. The common single difference method used in the literature compares the difference of regional economic growth before and after the implementation of the project to judge the effect of the policy on economic growth, but its conclusion may be inaccurate. In addition to many other factors that affect regional economic growth, other policies issued during the same period may also enable cities that have not implemented carbon sink afforestation to develop. These factors will affect the accuracy of the evaluation results. Therefore, the effect of carbon sink afforestation needs to be evaluated under a more scientific DID method, because the model combines temporal and spatial differences by setting up control groups and treatment groups, which mitigates the effect of other unpredictable factors. In this study, we compare the empirical results of the single-difference method and the DID method.

For the DID method, we used the following model:

$$Y_{it} = \beta_0 + \beta_1 \cdot \text{treated} \cdot t + \Sigma \beta_x \cdot \text{control} + r_i + y_t + \varepsilon_{it} \quad (1)$$

In Formula (1), Y_{it} is a proxy variable that measures the economic development level of the county, β_0 is a constant term, "treated" is used to distinguish the treatment group from the control group, t is a dummy variable used to distinguish between before and after project implementation, the cross-product term "treated·t" is the core explanatory variable for measuring whether the carbon sink plantation project is implemented, β_1 represents the net effect of carbon sink plantation on the county's economic development, β_x represents

the coefficient of each control variable, "control" includes the added value for the primary industry (pri), the added value for the secondary industry (sec), various loan balances of financial institutions at the end of the year (fin), general fiscal budget income (inc), and expenditure (exp), r_i refers to controlling individual fixed effects, y_t represents time fixed effects, and ε_{it} is a random interference term.

The above model was used to estimate the average benefit of carbon sink plantation projects. We further examined the dynamic effects of the carbon sink plantation project on economic development since the implementation of the project using the following model:

$$Y_{it} = \beta_0 + \sum \beta_K \, fcsp_k + \sum \beta_x \cdot control + r_i + \varepsilon_{it} \quad (2)$$

In Formula (2), $fcsp_k$ is the cross-product term "treated $\times$ t_k", which is a dummy variable for the k^{th} year since the carbon sink plantation project has launched in a county. After the carbon sink plantation project is implemented in this county, it will be assigned a value of 1 only in the k^{th} year of implementation, and a value of 0 in other years. The coefficient β_k is used to represent the economic benefits brought by the implementation of the policy in the k^{th} year after the implementation of the project.

To analyze the effect mechanism of carbon sink plantation projects on economic development, the following model settings were used:

$$control = \beta_0 + \beta_A \cdot treated \cdot t + \varepsilon_{it} \quad (3)$$

Each variable of the control variables is used as an explained variable in this formula, and we perform OLS regression with policy variables cross-multiplied respectively.

4.3. Variables

4.3.1. Explained Variable

The explained variable Y_{it} represents regional GDP level. In accordance with the common practice in the literature, this study uses the logarithmic value of GDP (LnGDP) of the region as the explained variable. Among these, taking into account the comparability of the data, this study uses 2006 as the base period to calculate the actual annual GDP by dividing the nominal GDP by the existing GDP deflator.

4.3.2. Core Explanatory Variable

The core explanatory variable is "treated·t". "Treated" is a policy dummy variable. That is, where the selected sample county has implemented the project, then "treated" equals 1; otherwise, "treated" equals 0. The variable t is a time dummy variable, used to indicate whether the project has been implemented or not: after the project is implemented (after 2011) t = 1; otherwise, t = 0. The two together form the cross-product term "treated·t", which is used to indicate whether a county has implemented a carbon sink plantation project in a certain year.

4.3.3. Control Variables

Among the control variables, the added value of the primary and secondary industries (pri, sec) were selected to reflect the composition of the regional industrial structure. Zhubing et al. [37] studied the changes in the regional economy and industrial structure in the Yangtze River Delta and concluded that the upgrading and adjustment of the industrial structure will affect the economic development of the region. Regarding the relationship between industrial structure changes and economic development, academic circles generally hold opposite views. For example, Peneder M et al. [38] suggest that industrial structure adjustment promotes economic development, while Baumol WJ [39] indicate that industrial structure adjustment inhibits economic growth.

Adam Smith's "The Wealth of Nations" believes that the increase in capital depends on savings, and capital accumulation is the source of wealth. The level of regional capital accumulation can mainly be reflected by the level of household savings and the level

of investment in fixed assets. The local economy, especially in this study, refers to the economic development of rural areas, which is usually affected by the capital stock of the county. First of all, it can increase the enthusiasm for investment or promote the consumption level of the region under the condition of high residents' savings rate, thereby driving economic growth. For example, in their Kosovo review study, Ribaj et al. [40] used the Granger causality test to prove that saving has a significant positive effect on economic growth. In view of the fact that this study cannot obtain the explanatory variables related to fixed asset investment, we only use the annual household savings deposit balance (sav) to represent the savings level of each county in that year.

Financing is another important driving force for county economic development. Some scholars believe that the development of rural finance is an important indicator to measure rural revitalization. Rural finance has also become the focus of many economists in recent years. Pradhan et al. [41] examined the empirical results of OECD countries and showed that financial development supports long-run economic growth. Therefore, we selected the indicator of the loan balance of financial institutions (fin) at the end of the year in each county.

This study also selects the general budget income (inc) and expenditure (exp) of local finance to represent the fiscal revenue and expenditure level of each county, respectively. The level of county public service depends on a reasonable local fiscal revenue and expenditure structure, which is also an important prerequisite for creating a suitable external environment for local economic development. The empirical research of Xiong Yunyang [42] shows that local fiscal expenditure has a significant positive effect on GDP growth. The empirical analysis and research of Wei Shaoxing [43] and Li Xin [44] have shown that the total local fiscal revenue and the general budget revenue of local finance usually maintain a highly positive correlation with local GDP growth.

Table 1 provides the definition of the main variables mentioned above.

Table 1. Definition of variables used in the study.

Type of Variable	Variable	Definition
Explained variable	lngdp	Logarithm of regional real gdp (based on 2006)
Core explanatory variables	Treated·t	Dummy, take 1 for the implementation of this project, 0 for non-implementation
Control variable	pri	Added value of primary industry (ten thousand yuan)
	sec	Added value of secondary industry (ten thousand yuan)
	inc	General budget revenue (ten thousand yuan)
	exp	General budget expenditure (ten thousand yuan)
	sav	Resident savings deposit balance (ten thousand yuan)
	fin	Balance of various loans of financial institutions at the end of the year (ten thousand yuan)

The statistical characteristics of the main variables are listed in Table 2. The sample size refers to the value of 56 counties from 2006 to 2018, the mean refers to the average of 728 samples, and the standard deviation is calculated by the formula of standard deviation between each sample and the mean.

Table 2. Descriptive statistics of variables used in the study.

Variable	Sample Size	Mean	Std. Dev	Minimal	Maximal
lngdp	728	13.5267	0.82187	10.7885	15.2857
treated	728	0.0714	0.25772	0	1
pri	728	29.4810	23.45258	2.0852	133.7041
sec	728	62.9834	72.69100	1.4758	680.5567
inc	728	6.8961	7.04521	0.2988	51.6285
exp	728	22.4380	17.50345	1.1279	85.0431
sav	728	103.8260	89.45256	4.0246	584.2586
fin	728	63.2306	73.19603	1.8917	643.4366

5. Empirical Analysis

5.1. Propensity Score Matching and Balance Test

The premise of PSM is that the propensity score values of the experimental group and the control group have a common value range; that is, they satisfy the common support hypothesis. Figure 1 shows the results of the joint support hypothesis test. It can be seen that, except for individual non-pilot cities, the propensity scores of other pilot cities and non-pilot cities are within the common value range, which indicates that the common support hypothesis is satisfied.

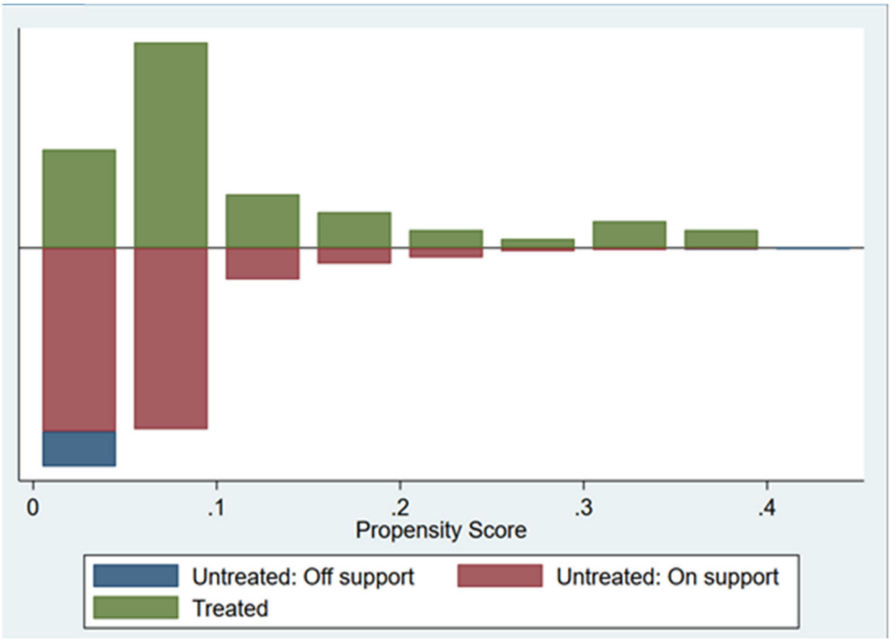
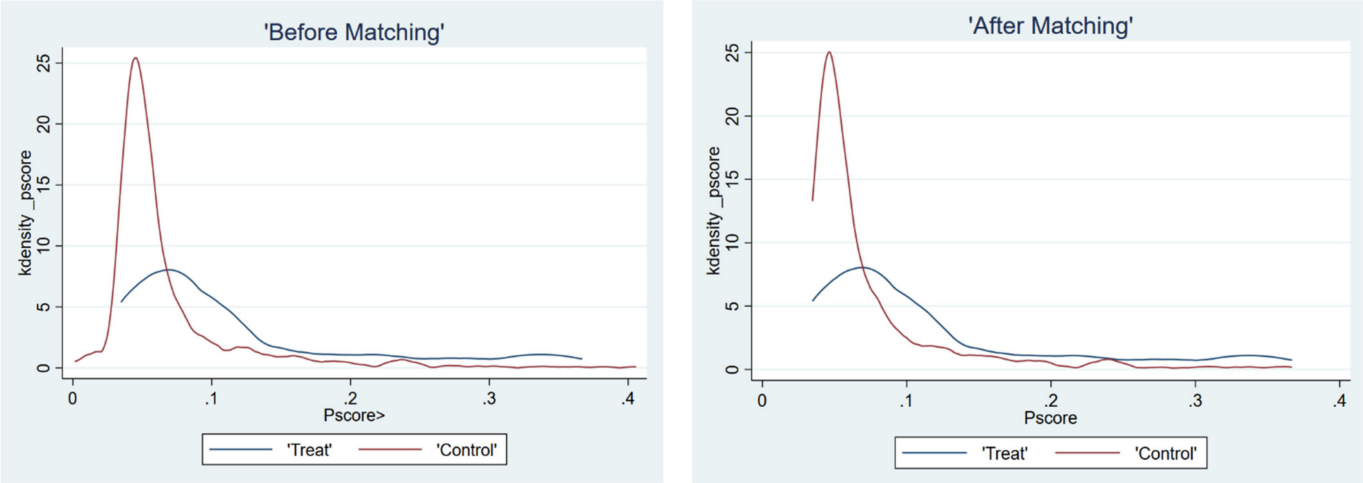


Figure 1. Common support hypothesis testing results.

Stata16.0 software was used for the empirical analysis in this study. PSM uses the kernel matching method that is commonly used in the policy effects literature. After estimating the propensity score through the Logit model, the kernel matching method was used to determine the weight of each sample according to the score value, the samples with the same propensity score value were matched, and 657 sample values were obtained. Figure 2 reports the changes in the nuclear density function of pilot cities and non-pilot cities before and after matching. It can be seen that after the PSM, the difference in the kernel density function of the two was relatively reduced, indicating that the pilot city found non-pilot cities that match it, thereby reducing the subsequent comparative analysis error.



(**a**) (**b**)

Figure 2. Changes in kernel density before (**a**) and after (**b**) matching.

The matching results were then tested for balance. The key to the balance test is to observe the error reduction in each control variable. The results are shown in Table 3. Table 3 shows that after matching, the standard deviation of other variables except the added value for the secondary industry were less than 20%, and the deviation of added value for the secondary industry was 20.4%, which is acceptable. Comparing the results before matching, the standard deviation of each variable was greatly reduced. The *p*-value of the *t*-test was greater than 0.05 (Table 3), indicating that there was no significant difference between the matched treatment group and the control group in the selected variables; that is, the result of the *t*-test does not reject the null hypothesis that there is no systematic difference between the treatment group and the control group.

Table 3. Matching balance test results of carbon sequestration afforestation projects.

Variable	Unmatched Matched	Mean Treated	Mean Control	% Reduct % Bias	% Reduct |Bias|	*t*-Test *t*	*t*-Test *p* > |*t*|	V(T) V(C)
pri	U	36.59	28.934	31.9		2.27	0.023	1.12
	M	36.59	36.514	0.3	99.0	0.01	0.989	0.67
sec	U	99.072	60.207	44.1		3.75	0.000	2.26
	M	99.072	81.087	20.4	53.7	0.99	0.323	1.72
inc	U	9.7974	6.6729	38.1		3.10	0.002	1.91
	M	9.7974	8.8189	11.9	68.7	0.57	0.570	1.35
exp	U	28.69	21.957	34.7		2.68	0.007	1.59
	M	28.69	27.564	5.8	83.3	0.27	0.787	1.06
sav	U	149.23	100.33	48.1		3.83	0.000	1.78
	M	149.23	135.92	13.1	72.8	0.60	0.551	1.06
fin	U	82.105	61.779	27.3		1.93	0.054	1.10
	M	82.105	73.794	11.1	59.1	0.58	0.565	1.17

The treatment group and the control group matched by the PSM method passed the balance test.

5.2. DID Model

To compare the results of the PSM-DID regression, we also performed the OLS regression of the single-difference method at the same time. The results are shown in Table 4.

Table 4. The average effect of carbon sink plantation projects on county economic development.

	LNGDP			
	(1)	**(2)**	**(3)**	**(4)**
Carbon sink plantation policy	0.318 * (0.139)	−0.108 (0.068)	0.832 *** (0.261)	0.205 (0.147)
pri		0.015 *** (0.001)		0.014 *** (0.001)
sec		0.003 *** (0.001)		0.004 *** (0.000)
inc		0.030 *** (0.005)		0.030 *** (0.005)
exp		−0.002 (0.001)		0.000 (0.001)
sav		0.003 *** (0.000)		0.004 *** (0.000)
fin		−0.002 *** (0.001)		−0.005 (0.001)
Constant Term	13.504 *** (0.031)	12.546 *** (0.036)	13.288 *** (0.040)	12.646 *** (0.030)
N	728	728	657	657

* and *** indicate significance at 10% and 1% level, respectively.

In columns 1 and 2 of Table 4, the variable "carbon sink plantation policy" in these two columns only refers to "treated" rather than the cross-product item. Column 1 lists the effects of carbon sink plantation projects on annual economic growth without considering the effect of various control variables on economic growth. According to the OLS regression results, it can be seen that the implementation of the carbon sink plantation had a positive effect on economic development, and the coefficient was significant at the 10% level. Column 2 shows the parameter estimation results after adding some socioeconomic control variables. The coefficients of the core explanatory variables were negative but not significant. Overall, the OLS regression effect was not significant, and the effect of unobservable factors was not considered, so the estimated results were biased.

Columns 3 and 4 of Table 4 include the results of the PSM-DID regression, which show the results of DID after matching using the kernel matching method. The variable "carbon sink plantation policy" in these two columns refers to the cross-product item "treated·t". The estimated results in column 3 did not add other control variables, and the coefficient of "treated·t" was significantly positive at the 1% level. This result shows that the implementation of carbon sink plantation projects has significantly positively promoted the economic development level of various regions in Guangdong Province. The results in column 4 show that the coefficient of the cross-product term "treated·t" was still significantly positive, and the conclusion that the implementation of carbon sink plantation projects has a significant role in promoting regional economic development holds.

The regression results shown in column 4 include consideration of the effect of other control variables on the economy. It can be seen that the coefficients of the added value of the primary industry and the added value for the secondary industry are both positive. Because of the limitation of the data acquisition, the added value of the tertiary industry could not be obtained. Therefore, it was impossible to discuss the effect of carbon sink plantation projects on the optimization of the regional industrial structure. However, the positive added-value coefficients of the primary and secondary industries indicated that the intra-industry upgrade will promote regional economic development. The contribution of the two industries to economic growth was roughly equal, and the role of the primary industry was more significant. The coefficient of fiscal income was positive and more

significant, which shows that local fiscal income has a role in promoting regional economic development. However, the coefficient of local fiscal expenditure was positive but not significant. A possible explanation is that the economic benefits of local government public expenditure lag or that it is related to the unreasonable structure of fiscal expenditure in some counties. The coefficient of the balance of household savings deposits was significantly positive, which indicates that when the savings level of residents increases, their potential to participate in social investment will increase, and investment has a positive role in promoting local economic development. The coefficient of loan balance of financial institutions was negative but not significant. Wang Xiaohua [45] shows that in rural areas in central China, low-producing farmers will be affected by financial repression, because capability limitations restrict them to lending funds instead of reaping income growth. In the past few decades, the development of China's financial industry has caused a large number of transfers and losses of rural funds, which has exacerbated the dual structure of urban and rural areas [46]. The conclusion of this study may be explained by the above-mentioned theory, that is, financial loans may inhibit more economic development in rural areas than they promote.

Although the empirical analysis has shown that the implementation of carbon sink plantation projects does have a significant role in promoting local economic development, it is necessary to conduct a dynamic analysis to study whether the promotion effect of this policy is continuous or temporary. The average effect model cannot analyze whether the economic benefits of carbon sink plantation projects are current or lagging. According to the literature, carbon sink plantation projects usually lead to slow returns because of long afforestation cycles. Therefore, further discussion on this issue is needed. Furthermore, this study used Formula (2) to calculate the dynamic effects of the project on local economic development. By assigning values to the $fcsp_k$ variable each year, we studied whether the implementation of the project could promote the economic development of the region sustainably, and whether there was a difference between the initial and long-term benefits. The results are shown in Table 5.

Table 5. Dynamic effect of carbon sink plantation projects on county level economic development.

	lngdp	**Std. Dev**
fcsp2	−0.064	0.161
fcsp3	−0.273	0.164
fcsp4	−0.245	0.163
fcsp5	−0.308	0.163
fcsp6	−0.140	0.161
fcsp7	0.014	0.161
fcsp8	0.227	0.162
pri	0.014 ***	0.001
sec	0.005 ***	0.000
inc	0.028 ***	0.004
exp	−0.002	0.001
sav	0.004 ***	0.000
fin	−0.005 ***	0.001
_cons	12.600 ***	0.024
N	675	

*** indicate significance at 1% level.

The estimated results in Table 5 show that the coefficients of fscp in the past five years of project implementation were all negative, although they were not significant, but this indicates that the implementation of carbon sink plantation projects is likely to depress local economic development. Taking into account the unique nature of the project, the reason may be that the carbon sink plantation project cannot bring sufficient economic benefits in the short term. From the perspective of farmers, the forest land where carbon sink plantation activities were carried out in some areas may have been agricultural land, and

therefore had a crowding-out effect on local agricultural development. In a short period of time, farmers have no way to immediately obtain income through nonagricultural activities except for government subsidies, which has a corresponding inhibitory effect on local economic development. From the government's point of view, in the first few years of afforestation, there may be more problems, such as forestry maintenance and farmer subsidies, making the short-term income less than the expenditure. However, it is not difficult to see that the coefficient becomes positive and gradually increases over time, indicating that the implementation of the carbon sink project drives the local economic development increasingly over time.

In summary, the DID method shows the average effect and dynamic effect of the project. The results indicate that a carbon sink plantation promotes economic growth, and the economic benefits brought by the carbon sink plantation project do not take effect immediately, and there may even be some obstacles in the early stages. Therefore, there is a lag in policy effect. On average, economic benefits began to gradually appear from the sixth year after the project is implemented.

5.3. Parallel Trend Test

The key identification hypothesis of the DID model is that non-pilot areas provide effective counterfactual changes for the policy treatment effects of pilot areas [47,48]; that is, before the implementation of carbon sink plantation projects, the development trend between the treatment group and the control group was the same, and there was no systematic difference over time. To ensure the basic assumption was met, this study followed the parallel trend test method of DID and performed regression for the first 5 years and the last 7 years of the treatment period. The regression results in Figure 3 and Table 6 show that before the implementation of carbon sink plantation projects, there was no systematic difference in the time trend between the pilot area and non-pilot area, which means it satisfied the parallel trend assumption.

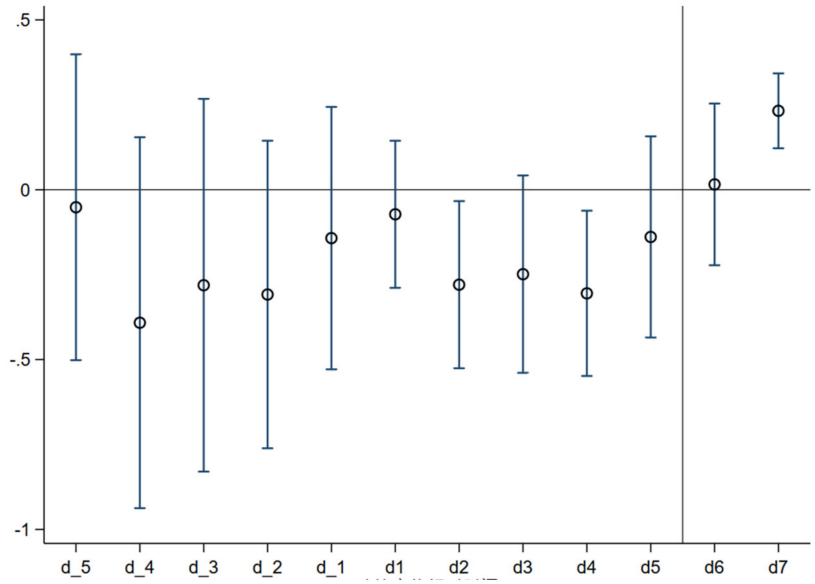


Figure 3. Parallel trend test.

Table 6. Parallel trend test.

lngdp	Coef.	Robust Std. Err	*t*	*p* > *t*	[95% Conf.	Interval]
d_5	−0.0515611	0.2733108	−0.19	0.850	−0.5882305	0.4851083
d_4	−0.3914662	0.3314995	−1.18	0.238	−1.0423940	0.2594619
d_3	−0.2810855	0.3330818	−0.84	0.399	−0.9351204	0.3729495
d_2	−0.3084475	0.2748416	−1.12	0.262	−0.8481228	0.2312278
d_1	−0.1424643	0.2345559	−0.61	0.544	−0.6030351	0.3181065
d1	−0.0722975	0.131454	−0.55	0.583	−0.3304188	0.1858238
d2	−0.2794956	0.149389	−1.87	0.062	−0.5728338	0.0138426
d3	−0.2485476	0.1763574	−1.41	0.159	−0.5948407	0.0977454
d4	−0.3049995	0.1477121	−2.06	0.039	−0.5950450	−0.0149541
d5	−0.1390086	0.1797845	−0.77	0.440	−0.4920311	0.2140138
d6	0.0157547	0.1445272	0.11	0.913	−0.2680371	0.2995464
d7	0.2323836	0.0669359	3.47	0.001	0.1009492	0.3638181
pri	0.0141618	0.0007757	18.26	0	0.0126386	0.0156849
sec	0.0046177	0.0004840	9.54	0	0.0036672	0.0055681
inc	0.0284408	0.0047736	5.96	0	0.0190673	0.0378142
exp	−0.0021334	0.0011828	−1.80	0.072	−0.0044559	0.0001891
sav	0.0037401	0.0004664	8.02	0	0.0028242	0.0046560
fin	−0.0047624	0.0006849	−6.95	0	−0.0061073	−0.0034176
_cons	12.6120000	0.0313910	401.77	0	12.5503600	12.673640

5.4. Robustness Test

In addition to the implementation of carbon sink plantation projects, other policies or random factors that have not been considered in this study may also lead to differences in regional economic development, which are not related to the research variables of this study, invalidating the conclusions drawn from the above empirical analysis. To test whether there were such influencing factors, this study adopted the method of the time placebo test to assume that the year of carbon sink plantation was unified two years earlier or two years later. If the core explanatory variable was still significant at this time, it means that economic development was probably due to other policy changes or random factors, rather than carbon sink plantation projects. Therefore, this study assumed that 2009 and 2013 are the implementation years, and the regression results obtained are shown in Table 7.

Table 7 shows that the corresponding core variable interaction coefficients were not significant, which confirmed the robustness of the benchmark regression results in this study. That is, the introduction of the time placebo test in the sample confirmed that the economic growth in this model was not brought about by other factors, but by the carbon sink plantation project. The model passed the robustness test.

5.5. Analysis of the Effect Mechanism

From the above tests, we have learned that the implementation of carbon sink plantation has a positive effect on economic development, but the mechanism of its effect on economic development during the implementation process has not been analyzed; that is, how the carbon sink plantation promotes economic development. Therefore, according to the analysis of the influence mechanism in the second part of this study, we regarded each control variable as the representative factor of the four aspects of industrial structure, capital accumulation, economic income, and fiscal revenue and expenditure, and investigated whether the carbon sink plantation had an effect on these important economic growth drivers.

As seen in Formula (3), the added values for the primary and secondary industries, fiscal year income and expenditure, household savings rate, and financial loan rate were used as the explanatory variables, and STATA was run to perform ordinary least squares regression (OLS) on the core explanatory variables "treated·t" in turn. The results of this model are shown in Table 8.

Table 7. Robustness test.

	lngdp	
	2009 Year	**2013 Year**
Treated·t	0.158	0.070
	(0.106)	(0.091)
pri	0.014 ***	0.014 ***
	(0.001)	(0.001)
sec	0.004 ***	0.004 ***
	(0.000)	(0.000)
inc	0.029 **	0.030 ***
	(0.004)	(0.004)
exp	0.000	0.000
	(0.001)	(0.001)
sav	0.004 ***	0.004 ***
	(0.000)	(0.000)
fin	−0.005 ***	−0.005 ***
	(0.001)	(0.001)
_cons	12.640 ***	12.637 ***
	(0.025)	(0.025)
N	675	675

** and *** indicate significance at 5% and 1% level, respectively.

Table 8. Effect mechanism of carbon sink plantation projects on economic development.

	pri	**sec**	**inc**	**exp**	**sav**	**fin**
Treated·t	16.708 ***	83.3506 ***	6.861 ***	19.667 ***	107.1307 ***	64.991 ***
	(4.194)	(11.135)	(1.139)	(3.034)	(15.299)	(10.840)
_cons	29.162 ***	56.336 ***	6.331 ***	21.382 ***	98.675 ***	55.005 ***
	(0.913)	(2.424)	(0.248)	(0.661)	(3.331)	(2.360)
N	675	675	675	675	675	675

*** indicate significance at 1% level.

All the coefficients in each column in Table 8 were positive and highly significant, indicating that carbon sink plantation can promote regional economic development by promoting the development of primary and secondary industries, increasing local fiscal revenue and expenditure, expanding capital stock, and increasing residents' economic income. It is worth noting that in the conclusions drawn from Table 4, fiscal expenditures were not significant in promoting the economic development of Guangdong Province, and the financial loan rate was even more of an obstacle to economic development. It shows that even if a carbon sink plantation can produce positive economic effects on these two aspects, the unreasonable fiscal expenditure structure of local governments in other areas and the inefficient financial industry development level will reduce this positive effect.

In summary, the effect mechanism of carbon sink plantation projects to stimulate economic growth was achieved by promoting the development of the primary and secondary industries, increasing local fiscal revenues and expenditures, increasing household savings, and enhancing the vitality of financial loans.

6. Conclusions and Recommendations

6.1. Conclusions

Based on the panel data of 56 counties in Guangdong Province from 2006 to 2018, this study used the PSM-DID method to study the net effect of the implementation of the Guangdong Changlong carbon sink plantation project on the economic development of the local counties. The research shows that the implementation of the carbon sink plantation project had a significant role in promoting the economic development of counties in Guangdong Province. However, the promotion effect had a significant lag. In the first five

years, it may even have a negative effect that hinders regional economic development. On average, it will take at least six years for the promotion of regional economic development to appear, and the increase will gradually become apparent over time. Because the carbon sink plantation project has the special characteristics of high initial investment and a long return cycle, it may result in low willingness of farmers to participate and insufficient financial input budget, making it difficult to show the economic benefits in the short term.

In addition, carbon sink plantation projects were positively correlated with the added value of primary and secondary industries (pri, sec), local fiscal income and expenditure (inc, exp), the annual household savings deposit balance (sav), and the balance of loans from financial institutions at the end of the year (fin). This finding suggests that the carbon sink plantation project stimulates economic growth by promoting the development of the primary and secondary industries, increasing local fiscal revenues and expenditures, increasing household savings, and enhancing the vitality of financial loans.

In general, carbon sink plantation projects can positively promote the economic development of Guangdong Province, and the promotion effect becomes increasingly apparent over time.

6.2. Recommendations

Combining the above conclusions and the current status of forestry carbon sink development in Guangdong Province, we propose the following recommendations for the follow-up development of carbon sink plantation projects.

First, establish and improve a long-term stable mechanism and transaction management system for carbon sink afforestation projects at the policy level. The afforestation project has a time period of at least several decades, during which there are unpredictable potential natural risks and market fluctuation risks. Therefore, to maximize long-term benefits, legislation to regulate project development, protect the legitimate rights and interests of carbon sink traders, and ensure that projects can obtain long-term and stable funding and technical support are required.

Second, stimulate market demand for carbon sinks. On the one hand, the state stipulates carbon emission quotas, issues carbon emission permits, and reasonably levies carbon taxes on enterprises, compulsorily forcing high-emission enterprises to purchase forestry carbon sinks on their own. On the other hand, by expanding the visibility of forestry carbon sinks, the development of the voluntary carbon sink market is promoted. At the micro level, financial market participants, especially companies engaged in high-polluting industries, can invest in carbon sink plantation projects or purchase forestry carbon sinks. This will not only compensate for the company's own excessive carbon dioxide emissions and avoid environmental damage but also allow them to buy and sell carbon sinks quota through the carbon sink trading market in order to gain profits.

Third, broaden financing channels. The government can use the leverage of funds through financial discounts to attract more investment. At the same time, forestry companies can use appropriate risk and benefit sharing mechanisms for project financing.

6.3. Future Research

Although this article provides some valuable findings for the implementation of carbon sink plantation projects, there are inevitably some limitations. Due to limitations in relevant data statistics and access, our study is limited to county-level data from Guangdong Province and does not involve other regions of China and other emerging market countries. Therefore, whether the research conclusions can be extended to these regions requires further empirical testing. Further research can attempt to use data from other provinces of China or other countries in order to analyze and compare their connections and differences and provide a theoretical basis for the development of carbon sink plantation projects in different regions.

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